PB-218 401

MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS DE GRAY RESERVOIR QUACHITA RIVER ARKANSAS-LOUISIANA

Public Health Service
Dallas, Texas

November 1961

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

14

U.S.P.H.S. Reg. 7

PB 218 401

MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS

DE GRAY RESERVOIR

OUACHITA RIVER

ARKANSAS-LOUISIANA

RECEIVED
LIBRARY
MAY 13 1969
FWPCA, OHIO BASIN REGION
4676 COLUMBIA PKWY., CINTI., O. 45226

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. Department of Commerce
Springfield VA 22151

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

In Cooperation with the

DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Vicksburg, Mississippi

NOVEMBER 1961

46

TABLE OF CONTENTS

	Page
LIST OF TABLES	iii
LIST OF FIGURES	iv
I. INTRODUCTION	
Authority	I-1
Purpose and Scope	I-1
Acknowledgments	I-1
II. SUMMARY AND CONCLUSIONS	
Summary	II-1
Conclusions	II-1
III. DESCRIPTION OF PROJECT	
Location	III-1
Stream Flow	III-1
Water Quality	III-2
Pertinent Data	III-3
IV. DESCRIPTION OF STUDY AREA	IV-1
Geography	IV-1
Climate	IV-1
Principal Communities and Industries	IV-2
V. ECONOMICS AND POPULATION	V-1
Extractive Industries	V-1
Manufacturing	V-3
Retail Trade	V-5
Population	V-5

TABLE OF CONTENTS (Continued)

		Page
	Future Growth	V-6
	Population Projections	V-11
VI.	WATER REQUIREMENTS	VI-1
	Existing Sources	VI-2
	Additional Water Needs	VI-4
	Stream Quality Maintenance	VI-8
	Plan for Supplying Future Requirements	VI-17
VII.	BENEFITS OF STORAGE	VII-1
	Alternative Plan	VII-1
	Water Supply Benefits	VII-1
VIII.	BIBLIOGRAPHY	VIII-1
IX.	APPENDIX	
	Variations in Municipal Water Demand - Ouachita River Basin, Arkansas and Louisiana	EXHIBIT A
	Waste Assimilation Requirements - Projected 2010 Waste Loading	EXHIBIT B

LIST OF TABLES

		Page
Table 1.	Typical Water Quality, Ouachita River.	III-3
2.	Pertinent Data, DeGray Reservoir, Arkansas	III-4
3.	Pertinent Data - Existing Reservoirs	IV-3
4.	Value of Mineral Production, 1953-1958, Ouachita River Basin, Arkansas and Louisiana . . .	V-1
5.	Value of Crops and Livestock Sold, Ouachita River Basin, Arkansas and Louisiana.	V-3
6.	Number of Firms by Size and Type of Manufacturing, Ouachita River Basin, Arkansas and Louisiana, 1947, 1954 and 1958	V-4
7.	Retail Trade Developments, 1948-1958, Ouachita River Basin, Arkansas and Louisiana . . .	V-5
8.	Rural and Municipal Populations and Major Municipalities, Ouachita River Basin, Arkansas and Louisiana, 1910-1960.	V-6
9.	Present Municipal and Industrial Water Demands, Ouachita River Basin, Arkansas and Louisiana . . .	VI-1
10.	Characteristics - Ground Water Sources, Ouachita River Basin, Arkansas and Louisiana . . .	VI-3
11.	Projections - Municipal and Industrial Water Demands - 2010, Upper Ouachita River Basin, Arkansas	VI-4
12.	Projected Municipal and Industrial Water Demand - 2010, Lower Ouachita River Basin, Arkansas and Louisiana	VI-9
13.	Chemical Characteristics - Ouachita River, Upstream from Monroe, Louisiana.	VI-13
14.	Projected Water Requirements - 2010 - In Excess of Existing Source Yields, Ouachita River Basin, Arkansas and Louisiana.	VI-16

LIST OF FIGURES

		Following Page
Figure 1.	DeGray Reservoir, Ouachita River Basin, Arkansas - Louisiana, Vicinity Map.	III-1
2.	DeGray Reservoir, Population Trends, Ouachita River Basin - Louisiana.	V-12
3.	DeGray Reservoir, Population Trends, Ouachita River Basin - Arkansas	V-12

I. INTRODUCTION

Authority

A Memorandum of Agreement between the Secretaries of the Departments of Health, Education, and Welfare and the Army, dated November 4, 1958, establishes a working agreement in regard to the Water Supply Act of 1958. In a letter dated July 13, 1959, the District Engineer, U. S. Army Engineer District, Vicksburg, requested that the Public Health Service, under the terms of the Memorandum of Agreement, undertake water supply studies regarding the DeGray Project, Ouachita River Basin, Arkansas and Louisiana.

Purpose and Scope

This report presents data and information relevant to the determination of water requirements, to the year 2010, for municipal and industrial purposes in the Ouachita River Basin and how these needs may be met. As requested by the Corps of Engineers, this report includes an estimate of the annual benefits which could be ascribed to storage allocated to water supply.

Projections are made of the future economic development of the area. Measures which may be necessary for the preservation of stream quality are discussed.

Acknowledgments

Acknowledgment is gratefully made for the assistance of the Arkansas State Board of Health; Arkansas Water Pollution Control Commission; Industrial Research and Extension Center, University of Arkansas; The Crossett Company, Crossett, Arkansas; International Paper Company, Bagpak Division, Camden, Arkansas; Chambers of Commerce, water utilities and municipal officials of Camden, El Dorado, Arkadelphia, Malvern and Crossett, Arkansas; the Ouachita River Water District; Louisiana State Board of Health; Louisiana Stream Control Commission; International Paper Company, Bastrop, Louisiana; Olin-Mathieson Chemical Corporation, Forest Products Division, West Monroe, Louisiana; Chambers of Commerce, water utilities and municipal officials of Bastrop, Monroe, West Monroe and Ruston, Louisiana; and S. E. Huey & Company, Consulting Engineers, Monroe, Louisiana.

II. SUMMARY AND CONCLUSIONS

Summary

1. The proposed DeGray Dam site is situated on the Caddo River, a tributary to the Ouachita River, northwest of Arkadelphia in Clark County, Arkansas.

2. Water from storage in the proposed reservoir would be available for use throughout that portion of the Ouachita River Basin adjacent to the main stream. The area under consideration encompasses all or part of Pike, Clark, Hot Spring, Dallas, Nevada, Ouachita, Calhoun, Union, Bradley and Ashley Counties, Arkansas; and Union, Morehouse, Lincoln, Ouachita, Richland, Caldwell and Catahoula Parishes, Louisiana.

3. Caddo River water, which would be impounded in the DeGray Reservoir, is low in color, dissolved solids, and total hardness and has other quality characteristics which make it suitable for municipal and most industrial purposes after a minimum of treatment.

4. The major population and industrial centers markedly affecting water demands in the basin are Arkadelphia, Malvern, Camden, El Dorado and Crossett, Arkansas; and Bastrop, Monroe, West Monroe and Ruston, Louisiana.

5. The three largest water using industries in the basin are alumina reduction in the Malvern-Arkadelphia area; pulp and paper production at Camden, Crossett, Bastrop and West Monroe; and the manufacture of petroleum, petrochemical and chemical products at El Dorado and Sterlington (just north of Monroe).

Conclusions

1. Projections to the year 2010 indicate an increase in the total study area population from approximately 430,000 in 1960 to 774,000 in 2010. The population served by municipal water works systems would expand from approximately 230,000 in 1960 to 600,000 in 2010.

2. Expansion of the petrochemical, chemical, pulp and paper industries is projected in the Ouachita River Basin only if sufficient water is provided from the proposed DeGray Reservoir to meet projected water requirements and to assure that resulting wastes can be assimilated without decreasing water quality to unacceptable levels.

3. The projected demands for water in the critical area (stated as the average rate of use during the year of maximum demand) are:

a.	Municipal	10 mgd
b.	Industrial	160 mgd
c.	For Water Quality Control	110 mgd
d.	Total	280 mgd

4. The 280 mgd yield requirement is based on an assumed concentration of municipal and industrial developments in the immediate Camden area, which would be the most critical situation. If the anticipated development is not concentrated in this area but occurs at intervals downstream, better quality will result due to the increased ability of the stream to assimilate the wastes.

5. Based on the most likely alternative source, a single-purpose reservoir at the proposed Corps of Engineers project site, the annual benefit to be derived from storage to provide a firm yield of 250 mgd for the total water supply requirements of the Ouachita River Basin is $909,000.

III. DESCRIPTION OF PROJECT

Location

The Ouachita River is one of the principal tributaries of the Red River. It rises in the Ouachita Mountains in west-central Arkansas and flows in a generally southeasterly direction through Arkansas and Louisiana. 1/ See Figure 1. The Caddo River, a principal tributary, joins the Ouachita River near its headwaters at mile 426 and has a total drainage area of 490 square miles. The proposed dam site is located on the Caddo River approximately 8 miles above its mouth and 7 miles northwest of Arkadelphia, in Clark County, Arkansas.

Most of the Caddo River watershed is mountainous with elevations ranging from as high as 2,200 feet above mean sea level near the headwaters to 186 feet above mean sea level at the mouth. The dam site is located in a narrow portion of the valley near the lower limits of the mountainous terrain. 2/

The reservoir area will extend in a generally northwesterly direction up the Caddo River with some portions stretching into Hot Spring County.

Stream Flow 2,3,4/

Stage and discharge information for the Ouachita River is obtained from several gaging stations. Four current daily flow stations are located upstream from the Caddo River - one at Malvern, Arkansas; one at Blakely Mountain Dam; and two at Mount Ida, Arkansas, one on the South Fork Ouachita River and the other on the main Ouachita River. There are three current daily flow stations on the Ouachita River downstream from the Caddo River - Arkadelphia, Arkansas; Camden, Arkansas; and Monroe, Louisiana.

There are two gaging stations on the Caddo River - one at Glenwood, Arkansas, and the other at Runyan Bridge, Arkansas.

Monthly stream flow at the DeGray Dam site has been estimated by the Corps of Engineers, using the following gaging stations:

Hot Springs	January, 1923 - September, 1930
Remmel Dam	October, 1930 - June, 1936
Mountain Pine	July, 1936 - June, 1946
Runyan Bridge	July, 1946 - To date

The mean monthly flows based on these data have varied from a low of 8 cubic feet per second in August, 1936, to a high of 5,968 cubic feet per second in March, 1945.

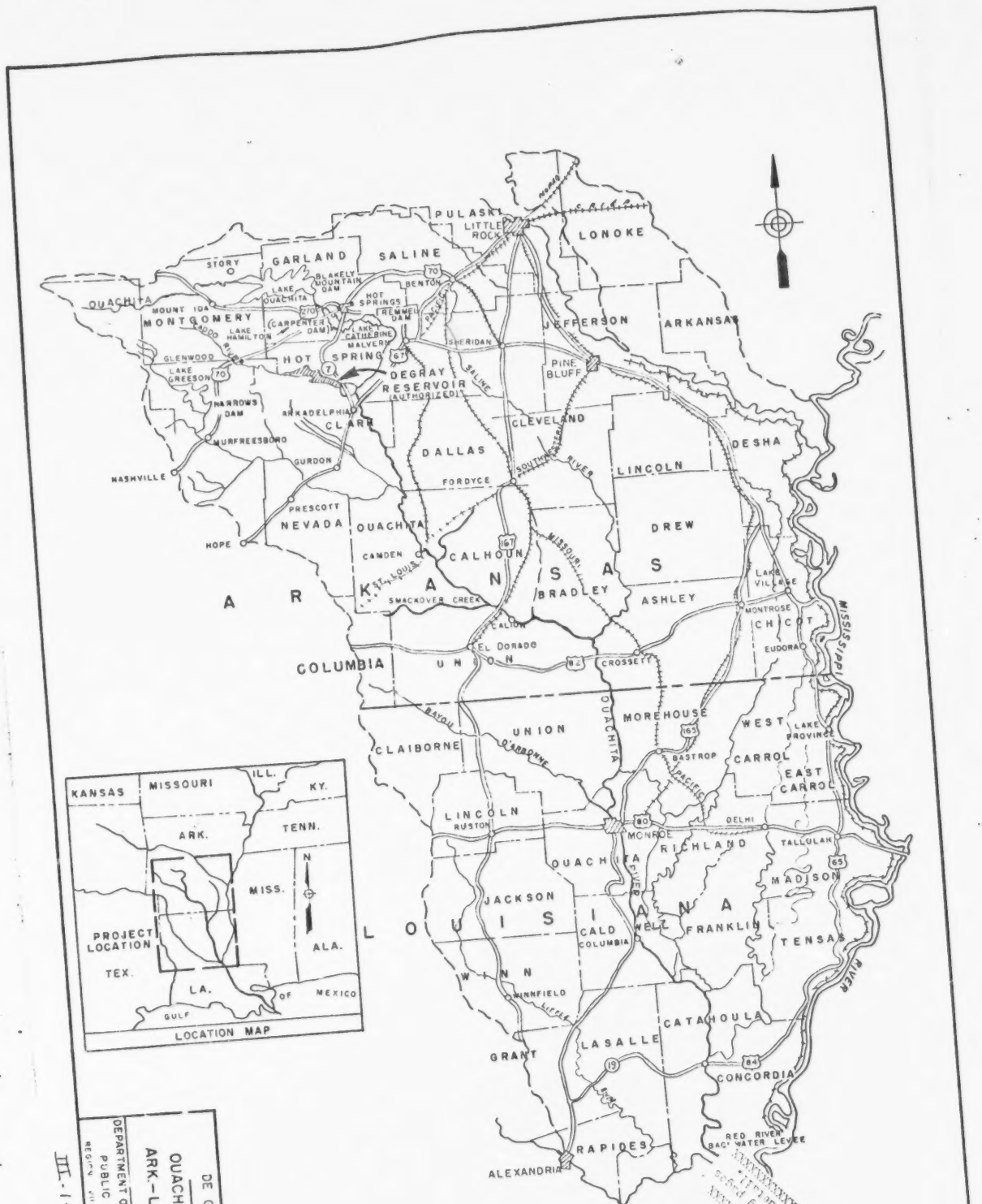


FIGURE 1

III-1-C

The Ouachita River's flow at Camden is affected by power releases from Lake Ouachita (Blakely Mountain Dam), Lake Hamilton (Carpenter Dam), and Lake Catherine (Remmel Dam) upstream from Malvern and Lake Greeson (Narrows Dam) on the Little Missouri River near Murfreesboro. Discharges at the Corps of Engineers' Camden gaging station have varied from a minimum monthly mean of 154 cfs in September, 1943 (minimum daily 125 cfs, same month), to a daily maximum of 243,000 cfs on April 3, 1945.

Water Quality 5,6/

Water quality data are available for the Arkadelphia, Arkansas, and Monroe, Louisiana, gaging stations. In addition, samples for raw water quality determination are collected routinely by the waterworks personnel of Malvern, Arkadelphia and Camden; all use the Ouachita River as a source of supply. 5,7/

Only a limited amount of stream quality data is available for the upper reaches of the Ouachita River Basin. These waters are, in general, of the quality found only in unpolluted mountain streams. Indications are that water from the Caddo River watershed, which will be impounded in the proposed project, is of approximately the same quality as the Ouachita River at Malvern since the watersheds are contiguous and of similar character. 6/ As can be seen in Table 1, these waters are of good quality, having characteristics which make them suitable for municipal and most industrial purposes after a minimum of treatment.

Little change takes place in the characteristics of the Ouachita River between Arkadelphia and Camden; but just downstream from Camden, Smackover Creek adds tons of mineral pollution from oil well operations. The oil field brines released to the Ouachita River via Smackover Creek and other tributaries make it unsuitable for use as a permanent source of municipal or industrial water supply (for most purposes). The quality of the Ouachita River below Smackover Creek is monitored by the U. S. Geological Survey at Felsenthal, Arkansas.

The Ouachita's quality gradually improves as dilution from tributaries containing only small quantities of natural or manmade mineral pollution is added to the stream. The quality is greatly improved at Monroe, Louisiana, but is not consistently of suitable quality for municipal and most industrial uses because of high chloride content. Typical results of chemical analyses are shown in Table 1.

The quality indicated in Table 1 for the upper reaches of the Ouachita River (above Camden) has remained essentially unchanged in the past few years. In 1958, the Arkansas Water Pollution Control Commission undertook a 5-year progressive cleanup of the oil field brine discharges. The success of the campaign will appreciably raise the quality of the Ouachita River below Camden. It is expected that

improvement will result to such a degree that the stream will be usable for municipal and industrial water supply purposes throughout its length.

Table 1

Typical Water Quality [5,7] Ouachita River

Sampling Point	Malvern Ark.	Arka-delphia Ark.	Camden Ark.	Felsenthal Ark.	Monroe La.
Date or Year	3/57	1954-5	3/56	1954-5	1954-5
pH	6.8	7.0	6.0	6.8	6.4
Color	---	9	---	19	40
Maximum	---	---	---	45	80
Alkalinity ppm					
Phenolphthalein	0	---	0	---	---
Total	15.0	---	13.0	---	---
Hardness ($CaCO_3$) ppm					
Total	34	36	24	257	227
Carbonate	15	29	0	137	126
Noncarbonate	19	7	24	120	101
Sulfate ($SO_4^=$) ppm	2.0	8.4	8.0	13	12
Ca^{++} ppm	7.9	8.2	7.0	39	36
Mg^{++} ppm	3.45	2.1	1.6	9.6	8.7
Fe^{+++} ppm	0.12	---	0.6	---	0.1
Mn^{++} ppm	Trace	---	0	---	---
Chloride (Cl^-) ppm	8.0	---	9.1	---	---
Average	---	6.4	---	342	334
Maximum	---	17	---	2450	1730
Minimum	---	3.2	---	36	42
Total Solids ppm	35	55	124	714	640

Pertinent Data [2,8]

The proposed multipurpose dam for the DeGray Reservoir project will be of the earthfill type. Data covering its design features are shown in Table 2.

Table 2

Pertinent Data 8/
DeGray Reservoir, Arkansas

Drainage Area, Square Miles	453
Elevations:	
Minimum Pool, m.s.l.	367.0
Power and Water-Supply Pool, m.s.l.	408.0
Flood-Control Pool, m.s.l.	423.0
Spillway Crest, m.s.l.	423.0
Surcharge Pool, m.s.l.	444.1
Top of Dam, m.s.l.	450.0
Volumes:	
Minimum Pool, Acre-feet	261,500
Power and Water-Supply Pool, Acre-feet	393,200
Flood Control Pool, Acre-feet	227,200
Surcharge Pool, Acre-feet	416,600
Firm Yield, from Water Supply Storage, mgd	250

IV. DESCRIPTION OF STUDY AREA

The Ouachita River drainage basin is about 300 miles long and 150 miles wide at its widest point. It embraces about 22,400 square miles of which 13,200 square miles are in Arkansas and the remainder in Louisiana. Principal tributaries are: Caddo River, Little Missouri River, Smackover Creek, Moro Creek, and Saline River in Arkansas; and Bayou Bartholomew, Corney Creek, Bayou La Fourche, and Tensas River in Louisiana.

The proposed project is located in the southern foothills of the Ouachita Mountains on one of the major headwater tributaries. The study area, as shown in Figure 1, includes the following counties and parishes which lie within the watershed of the Ouachita River proper: the counties of Pike, Clark, Hot Spring, Dallas, Nevada, Ouachita, Calhoun, Union, Bradley, and Ashley in Arkansas; and these parishes in Louisiana - Union, Morehouse, Lincoln, Ouachita, Richland, Caldwell and Catahoula.

The Ouachita River's headwaters region was not given detailed consideration since it is well watered and has a number of adequate sources of water supply which are more feasible than the proposed project.

Geography [1/]

In the headwaters area, the Ouachita Mountains consist of a series of narrow valleys and long ridges with elevations varying from 500 to 2,000 feet above sea level. Upstream from Arkadelphia, the Ouachita River drains these mountains through numerous short tributaries with a trellis-like pattern. Stream slopes are steep, averaging 12 feet per mile, in this region.

The study area is geographically bounded by this mountainous region on the north, the Saline River subbasin to the Ouachita on the east in Arkansas and the Bayou Bartholomew subbasin on the east in Louisiana. The area is bounded on the west by the Bayou Dorcheat and Red River Basins.

After leaving the mountains the Ouachita River enters the gently sloping coastal plains which have an average altitude of about 250 feet. Stream slopes average about 3 feet per mile in this region. In Louisiana, the river flows through the alluvial deposits of the Mississippi River valley at an elevation of about 100 to 150 feet.

Climate [1,2/]

The climate of the Ouachita River Basin is mild, having an average annual temperature of 65°F. January is the coldest month with an average temperature of 43°F, while July is warmest with an 83°F average temperature.

The basin lies in a region of moderately heavy rainfall, averaging about 50 inches annually. The heaviest rainfall occurs during the winter months.

Principal Communities and Industries

The major population centers within the study area are Arkadelphia, Malvern, Camden, El Dorado, Warren and Crossett, Arkansas; and Bastrop, West Monroe, Monroe and Ruston, Louisiana.

The northern portion of the study area contains several alumina reduction plants, and a large barite mining operation (all of Arkansas' barite is produced in Hot Spring County). The central and southern sections of the Ouachita River Basin contain a sizable pulp and paper industry and an extensive petroleum production and petroleum products industry. The southern end of the study area contains a number of chemical plants as well as pulp and paper production facilities.

Outside of the industrial areas the basin's economy is for the most part agricultural with a growing forest products industry producing pulpwood and saw timber.

Hydroelectric Power

There are four hydroelectric plants within the Ouachita River Basin, each served by a dam and reservoir: namely, Arkansas Power and Light Company's Carpenter and Remmel Dams, which form Lake Hamilton and Lak Catherine on the Ouachita River; Blakely Mountain Dam, which forms Lake Ouachita; and Narrows Dam, which forms Lake Greeson on the Little Missouri River. Pertinent data for these existing reservoirs are shown in Table 3.

Table 3

Pertinent Data - Existing Reservoirs 2/

	Federal Ownership		Non-Federal Ownership	
			Arkansas Power and Light Company	
	Blakely Mountain	Narrows	Carpenter	Remmel
River	Ouachita	Little Missouri	Ouachita	Ouachita
Miles above Mouth	487	105	468	465
Drainage Area, square miles	1,105	237	1,441	1,516
Type of Dam	Earth	Gravity Concrete	Gravity Concrete	Amburson Concrete
Elevations:				
Conservation Pool, m.s.l.	535.0	504.0	374	290
Power Pool, m.s.l.	578.0	548.0	400	305
Flood Control Pool, m.s.l.	592.0	563.0	---	---
Spillway, m.s.l.	592.0	563.0	374	290
Surcharge Pool, m.s.l.	610.2	580.2	---	---
Top of Dam, m.s.l.	616.0	581.0	405	315
Volumes:				
Conservation Pool, Acre-ft.	865,000	77,600	71,000	15,400
Power Pool, Acre-ft.	1,286,000	202,000	119,000	20,000
Flood Control Pool, Acre-ft.	617,000	128,000	---	---
Surcharge Pool, Acre-ft.	993,000	193,000	---	---
Power:				
Dependable Capacity, kw	65,000	14,000	56,000	10,000
Average Annual Output, kwhr times 10^6	156	28.4	103.7	49.2

V. ECONOMICS AND POPULATION

Municipal and industrial water demands will be centered at the principal cities in the area. Industrial expansion, population growth, and the accompanying increase in water use depend on growth factors both inside and outside the project area. Therefore, an examination of the economic environment is necessary, particularly in relation to national and competitive regional factors.

Extractive Industries

The extractive industries are of major importance in the present economy of the Ouachita River Basin.

Minerals 9/

Arkansas leads the Nation in barite production. This mineral is extensively mined in Hot Spring County, Arkansas, and used in oil and gas well "drilling mud." Since 1949, production has ranged from a high of 486,254 short tons (1956) to a low of 182,779 short tons (1958). Crushing facilities have been expanded, and it is expected that production can be continued at the current rate for a considerable time.

The central area of the Ouachita River Basin, including Ouachita and Union Counties in Arkansas, is rich in natural gas and petroleum. All of the parishes in the portion of the basin lying in Louisiana produce petroleum and natural gas. Lincoln Parish ranks third in production of natural gas liquids in Louisiana.

The total value of mineral extraction in the study area has ranged from $92 million to $109 million annually from 1953 through 1958. Most of the mineral production, as illustrated in Table 4, is found in Ouachita and Union Counties and in Lincoln and Richland Parishes.

Table 4

Value of Mineral Production, 1953-1958 9/
Ouachita River Basin, Arkansas and Louisiana
(Figures in millions of dollars)

Year	Arkansas Portion	Louisiana Portion	Basin Total
1953	$45.0	$51.2	$ 96.2
1954	50.0	42.2	92.2
1955	49.8	48.6	98.4
1956	49.5	55.1	104.6
1957	52.2	57.1	109.3
1958	46.1	51.7	97.8

Estimated crude petroleum production in this region totaled 19,319,000 barrels in 1959. Reserves are estimated at 280,160,000 barrels or sufficient to sustain the current production rate for about 14.5 years.10/ The search for additional oil and gas continues. During 1960, a total of 657 wells were drilled within the basin - 350 are petroleum producers, 81 are gas producers, and the remainder were dry holes. 9/ There are approximately 5,000 wells in the study area.

Forest Resources 11,12/

The forest resources of the ten county, seven parish study area are important to the industrial base. More than three-fourths (77.5 per cent) of the total acreage is devoted to commercial forests. This amounts to about 6 million acres of growing stock, with 70 per cent of the growing stock in softwoods, such as pine. Additional planting of pine is under way in the area.

The part of the study area in Arkansas is much more heavily wooded than that in Louisiana and is owned largely by corporations which employ professional foresters and use modern forest management techniques to provide maximum yield per acre from this land. Between 1946 and 1959, pulpwood production nearly doubled, from approximately 450,000 cords to 875,000 cords annually. 13/

Agriculture 14,15/

The number of farms in the study area has steadily decreased from 35,118 in 1945 to 27,139 in 1954. Coupled with this decline has been a significant reduction in the acres of cropland harvested from 765,993 in 1945 to 554,482 in 1954.

Unlike the declining trend in acres harvested, the value of crops sold registered a sustained gain between 1945 and 1954, rising from $20.9 million in 1945 to $30.8 million in 1950 and $29.6 million in 1954. During this same period the value of livestock and livestock products nearly doubled from $6.1 million in 1945 to $11.9 million in 1954. This situation is illustrated in Table 5.

Two parishes, Moreland and Richland, and one county, Ashley, had a considerable increase in value of crops sold and livestock and livestock products sold between 1945 and 1954, contrary to a declining trend in surrounding areas. (This increase was due to expanded production.)

Table 5

Value of Crops and Livestock Sold [14,15]
Ouachita River Basin, Arkansas and Louisiana

Year	Value of Crops Sold	Value of Livestock Sold	Total
1945	$20,629,022	$ 6,018,990	$26,648,012
1950	30,832,806	10,147,465	40,980,271
	27,391,865*	7,312,263*	34,704,128*
1954	29,661,734	11,944,965	41,606,699
	24,390,844*	9,401,882*	33,792,726*

*Adjusted to 1945 value of the dollar.

Manufacturing [16,17]

There has been notable growth in the manufacturing base in the Ouachita River Basin in the period between 1947 and 1958. The total number of employees increased from about 26,000 in 1947 to 29,000 in 1958 (from 15,000 in 1939), while the area's output, measured as value added, jumped from $119 million to $207 million ($181 million in 1947 dollars). These value figures do not include Calhoun County, as datum for this county is not available.

The industrial growth of the Ouachita River Basin has been affected by the expansion of three industries: alumina reduction; petroleum, chemical, and petrochemical products manufacture; and pulp and paper making. The two alumina reduction (aluminum ingot producing) plants are located in the extreme northern end of the basin adjacent to the hydroelectric power dams. The chemical industries are for the most part confined to Union County and Ouachita Parish in the central and south-central part of the basin. The pulp and paper industry likewise has grown in the central and southern portion of the basin.

The number of firms employing 20 or more persons increased slightly between 1947 and 1958; however, this was offset by a decline in the number of firms employing 100 or more. Although it would appear that total employment might drop under these circumstances, total manufacturing employment increased 3,000 during this period. Furthermore, there has been a shift away from employment in lumber products manufacture (exclusive of furniture) to other manufactures within the area. Table 6 shows these developments.

Table 6

Number of Firms by Size and Type of Manufacturing
Ouachita River Basin, Arkansas and Louisiana
1947, 1954 and 1958 16,17/

Type of Manufacturing Firms	Number with 20 to 99 Employees			Number with 100 Employees and Over			Total Number with Over 20 Employees		
	1947	1954	1958	1947	1954	1958	1947	1954	1958
Food and Kindred Products	12	18	19	--	--	2	12	18	21
Textile Mill Products	--	--	--	1	1	1	1	1	1
Apparel and Related Products	1	2	3	1	4	4	2	6	7
Lumber & Products (Exc. Furniture)	72	64	51	32	14	16	104	78	67
Furniture and Fixtures	1	2	2	1	2	2	2	4	4
Paper and Allied Products	2	4	7	15	18	12	17	22	19
Printing and Publishing	3	4	8	1	1	1	4	5	9
Chemicals and Allied Products	5	6	3	4	4	4	9	10	7
Petroleum and Coal Products	2	2	6	3	4	5	5	6	11
Stone, Clay and Glass Products	2	1	5	2	2	2	4	3	7
Primary Metals	1	3	2	1	3	3	2	6	5
Fabricated Metals	--	--	2	--	--	1	--	--	3
Machinery (Except Electrical)	--	--	2	--	--	--	--	--	2
Miscellaneous Manufactures	3	3	2	--	2	1	3	5	3
Total	104	109	112	61	55	54	165	164	166

Retail Trade [18,19]

The major industry of Monroe, Louisiana, is commerce rather than manufactures. It serves as a regional trade center for northern Louisiana, west-central Mississippi, and southern Arkansas.

The principal communities other than Monroe reflect the change occurring in the Ouachita River Basin. Only three or four of the 17 counties are growing agriculturally (as shown by the increased value of crops sold), while 14 of the counties are developing industrially (reflected in increased value added by manufactures). The remainder are experiencing a decline in agriculture which has resulted in limited retail trade development.

Between 1948 and 1958, the number of retail trade establishments in the study area decreased slightly. However, during the same period, the number of employees increased as did the sales volume. Substantial gains in employment were made in Ouachita County (Camden), Arkansas, and Ouachita Parish (Monroe), Louisiana. The over-all changes can be observed in Table 7.

Table 7

Retail Trade Developments, 1948-1958 [18,19]
Ouachita River Basin, Arkansas and Louisiana

	1948	1954	1958
Number of Establishments	4,685	4,310	4,280
Number of Employees	11,756	13,633	12,743
Sales Volume ($1,000)	248,465	309,873	335,675

Population [20]

The population in the Ouachita River Basin has been undergoing considerable change during the last 50 years. In 1910, there was a total population of 303,744 in the study area. Of this total, 240,781 were living on farms or outside of the organized settlements and can be classed as rural. The remainder, 62,963, were residents of municipalities.

By 1940, the rural population had grown to 275,165 while municipal population reached 138,374, making the area total 413,539. While the total population continued to increase after 1940, the rural segment decreased by approximately 75,000 between 1940 and 1960. The municipal population almost doubled during this time and more than offset the decline in the rural population segment.

All of the population centers were established and growing prior to 1950. In the last 20 years, the population of Warren has tripled; Bastrop and Ruston have doubled; Camden, El Dorado, Malvern, Monroe, and West Monroe have nearly doubled; and Arkadelphia has increased significantly. Crossett and Fordyce also have increased, though not to the same degree as the other population centers. Table 8 displays these trends.

Table 8

Rural and Municipal Populations and Major Municipalities 20/
Ouachita River Basin, Arkansas and Louisiana, 1910-1960

Study Area	1910	1920	1930	1940	1950	1960
Municipal	62,963	73,971	125,206	138,374	192,315	231,487*
Rural	240,781	247,365	273,622	275,165	222,082	198,825*
Total	303,744	321,336	398,828	413,539	414,397	430,312**
Arkansas						
Arkadelphia	2,745	3,311	3,380	5,078	6,819	8,041
Fordyce	2,794	2,996	3,206	3,429	3,754	3,921
Camden	3,995	3,238	7,273	8,975	11,372	15,686
El Dorado	4,202	3,887	16,421	15,858	23,076	25,168
Warren	2,057	2,145	2,523	2,516	2,615	6,661
Crossett	2,038	2,707	2,811	4,891	4,619	5,353
Malvern	2,778	3,864	5,115	5,290	8,072	9,518
Louisiana						
Bastrop	854	1,216	5,121	6,636	12,769	15,175
Ruston	3,377	3,387	4,400	7,107	10,372	13,940
Monroe	10,209	12,675	26,028	28,309	38,572	51,931
West Monroe	1,127	2,240	6,566	8,560	10,302	14,656

*Estimated
**Actual

Future Growth

From 1960 to 2010, the Nation is expected to double in population, producing an increase in the need for goods and services. Although all parts of the Nation will continue to contribute to the needs, the rate of increase in production will not be uniform in all areas.

An examination of the study area's ability to produce and market products and provide services to meet the increased demands will assist in the projection of water demand in the Ouachita River Basin. Each municipality is located adjacent to the Ouachita River except Warren, Arkansas, which is in the basin of Saline River, a major tributary to the Ouachita River. Projections for the Saline River Basin are contained in a report by the Public Health Service entitled "Municipal and Industrial Water Requirements, Benton Reservoir, Saline River, Arkansas," dated November 1960. 21/ Since the Warren area is considered in detail in that report, details are unnecessary to repeat here.

The Ouachita River Basin is rich in three natural resources -- water for hydroelectric power at its headwaters, timber and petroleum in the middle and lower reaches. An increase in demand is anticipated for all three.

Upper Ouachita River Basin

The four existing hydroelectric power stations in the upper Ouachita River Basin have contributed to the growth of the municipalities of that area and will continue to do so. The availability of electricity was in part responsible for the two alumina reduction plants located near Arkadelphia and Malvern, Arkansas. The alumina is produced in the Benton area of the upper Saline River Basin. Benton is the site of a 50 million ton deposit of bauxite, from which alumina is refined. 22/ (Current production rate is 1.6 million tons/year.)

The proximity of alumina and hydroelectric power provides the prospect for continued expansion of the aluminum industry in this area. The construction of the proposed project, with provision for hydroelectric power (40,000 kw) as one of its several purposes, should result in expansion of the aluminum industry in this area. Nevertheless, the growth would be limited by the amount of power available at a cost of 2 mills per kilowatt-hour or less. 23/ Furthermore, the number of sites usuable for hydroelectric power is limited. For these reasons, only a moderate (20 - 40 per cent of existing capacity) growth of the aluminum industry can be projected for the Arkadelphia-Malvern area. In addition, there are possibilities for industrial expansion in related chemical and primary metals fields.

The barite deposit in Hot Spring County has contributed to Malvern's growth to date; however, future expansion of the processing facilities is not expected. 24/

Lower Ouachita River Basin - Pulp and Paper 11,12,13,25,26,27/

The lower Ouachita River Basin (downstream from Camden) embraces a rich forest area covering three major Forest Survey regions -- the eastern half of southwest Arkansas, the eastern quarter of northwest Louisiana, and the western third of the North Delta Region. These regions are heavily forested, averaging 71 per cent of total area in commercial forest. Forest products, including pulp and paper are responsible for a large part of the economic growth in the study area. There are now five paper mills in the Ouachita River Basin -- one at Camden and two at Bastrop (all three are owned by International Paper Company), one at Crossett, and one at West Monroe.

Expectations are that by 2010, the growing demands of the United States for paper products will require approximately 96 million tons of woodpulp annually 25/ (1959 production - 24.3 million tons 27/). This pulp and paper products output will use an estimated 132 million cords of pulpwood. In 1946, the study area furnished 2.7 per cent of the pulpwood production in this country. By 1959, the area was supplying only 2.4 per cent of the country's requirement although producing nearly twice as much pulpwood. (U. S. production had increased nearly 2.2 times. 25,27/.) This is due in part to the timber utilization situation in the Louisiana portion of the lower basin. Almost 70 per cent of the total timber growth (production) has been going to the pulp mills. The usual split in timber use is 50 - 50 per cent between saw timber and pulpwood. Increased production is expected to keep pace with demand.

Cognisance should be taken of the fact that pulpwood requirements per unit of product output vary from process to process and even from mill to mill using the same basic process. Likewise, the number of employees required per ton of output is highly variable. Therefore, average figures were derived from data on the existing paper and pulp industries in Arkansas and Louisiana. 6,13,28,29/ Past and present production in the study area has been by the Kraft process, so it is further assumed that the use of this process and its refinements will continue.

The geographic distribution of the Ouachita River Basin's pulp and paper production will be governed by two factors: (1) location and availability of pulpwood and (2) the availability of water for process use, together with an adequate means of disposal for treated waste.

Some of Arkansas' most productive 19 million acres and Louisiana's 16 million acres of forest are located in and around the Ouachita River Basin. The majority of this wooded area is owned by forest products companies. The forest management practiced on the corporations'

holdings is responsible for the increasing harvests (without depletion) in the area under consideration. A portion of this area overlaps the area included in the Benton Reservoir, Saline River, Arkansas, report previously referred to. The long-range projection for Arkansas' pulp and paper industry shown in that report considered the resources in the lower Ouachita River Basin and made allowances so that this overlapping should not result in discrepancies. However, the projections for pulpwood use and water demand shown in the Benton Reservoir report assume that a water supply of satisfactory quality and quantity will be available in the Saline River Basin. In the absence of such a supply, production facilities would distribute differently in this region. It is necessary, therefore, to assume and consider two water supply situations in the lower reaches of the Ouachita River Basin. The first would be projected pulp and paper industry development for the DeGray project study area with the Benton Reservoir project furnishing water to the adjoining Saline River Basin. The other would be projected development in the absence of the proposed Benton Reservoir.

Although the Saline and lower Ouachita River Basins adjoin, their anticipated pulpwood yields vary. While anticipated 2010 yields in the Saline Basin will average three-fourths cord per acre, the lower Ouachita River Basin will average 1 cord per acre (without depletion) with the same order of management. 13/ A portion of the cordwood produced in the Saline River Basin would be diverted to production facilities in the lower Ouachita River Basin without the Benton Reservoir project, or one yielding comparable quantities of water to meet anticipated demands for that region.

Considering Benton and DeGray operating in concert, projected pulp and paper production would approach 1.9 million tons annually (5,100 tons daily) in the lower Ouachita study area and projected forest area yield of 3.3 million cords of pulpwood. Under these conditions, approximately 55 per cent of the study area total forest of 5.9 million acres will be required to meet the projected pulpwood requirements (3.3 million cords @ 1 cord/acre).

In the absence of the Benton project, production facilities would have to be distributed differently, with the lower Ouachita River Basin and other areas picking up production capacity which is unable to locate in the Saline River Basin due to lack of adequate water supply.

The pulpwood output of the Southwest and Ouachita Forest Regions of Arkansas will be available with a total of 10.5 million acres and an anticipated yield of 4.6 million cords. However, only a part of this, about 2.9 million cords (2010) could be utilized at pulp and paper production facilities in the lower Ouachita Basin. Louisiana's forest region would add a projected 1.4 million cords to the lower basin's timber resource base.

The projected pulpwood yield (approximately 50 per cent of the projected annual growth) could produce an estimated 7,500 tons of pulp and paper production, based on 1.75 cords per ton of output.

In recent years, roughly 60 per cent of Louisiana's and 50 per cent of Arkansas' timber output have gone to woodpulp production. Since the forest area in this region has been increasing gradually and growth has been keeping pace with and in some areas exceeding harvest, it would seem that enough pulpwood stock will be available to support the Ouachita River Basin's projected paper industry in 2010.

Petroleum and Chemicals

The El Dorado area of southern Arkansas has been one of the outstanding petroleum production centers in the southwestern United States. Natural gas and natural gas liquids are produced by the nearly 5,000 active wells in this region. Production to date totals more than 745 million barrels. As a result of this production, some petroleum refineries are in operation here. Furthermore, a rather sizable petrochemical and by-product chemical industry has developed in West Monroe, Louisiana, and in El Dorado, Arkansas. 28,29/ Here, the products of this industry include ammonia, ammonium nitrate, antifreeze, fertilizers, methanol, nitroparaffins, bromine, acids, naptha, and refined petroleum products. The demand for these products has been growing at an increasing rate and can be expected to continue for many years. Indications are that this industry will continue to grow in these areas near Monroe and El Dorado.

Manufacturing

Between 1939 and 1958, manufacturing employment nearly doubled, from 15,000 employees to 29,000. Most of the industries employing a significant number of workers are resource oriented, i.e., located adjacent to the natural resource which plays an important role in the production process, such as aluminum reduction or paper making. Future expansion in nonresource-oriented industries such as metal fabrication or garment making can be expected in the Ouachita River Basin. The production will probably be somewhat diversified.

In the northern portion of the study area, Hot Springs and Little Rock provide good markets for the output from small to moderate sized light industries. The ingot aluminum available from the alumina reduction plants in this area offer opportunities for location of some aluminum fabrication plants.

The southern portion of the area, with its expanding industrial trend for the most part established, provides opportunities for growth of many small light industries which could serve this expanding regional market.

Good transportation -- both highway and rail in the north and highway, rail, and water in the south -- is available to move the output from this area to regional, national, and international markets.

Monroe-West Monroe

The situation in and around the Monroe-West Monroe area is very favorable for continued growth. There are indications that this area, recently classified as a SMSA (Standard Metropolitan Statistical Area) is becoming the commercial center for a large part of Arkansas, Louisiana, and Mississippi. Furthermore, while the agricultural economy in other parts of the southern and southwestern United States is declining, it has been quite vigorous in this part of Louisiana. Monroe has been growing at a sustained rate of 3.3 per cent (above the national average of 1.5 per cent) without an outstanding industry other than commerce. Less than 10 per cent of its covered employment is in manufacturing as compared to Dallas, Texas, for example, which has a manufacturing employment of 17 per cent.

Projected expansion in the West Monroe industries adjacent to Monroe will affect growth in the metropolitan area favorably.

Other Growth Factors

Expectations are that retail and service establishments will grow in number and employment to keep pace with the increased population in the communities.

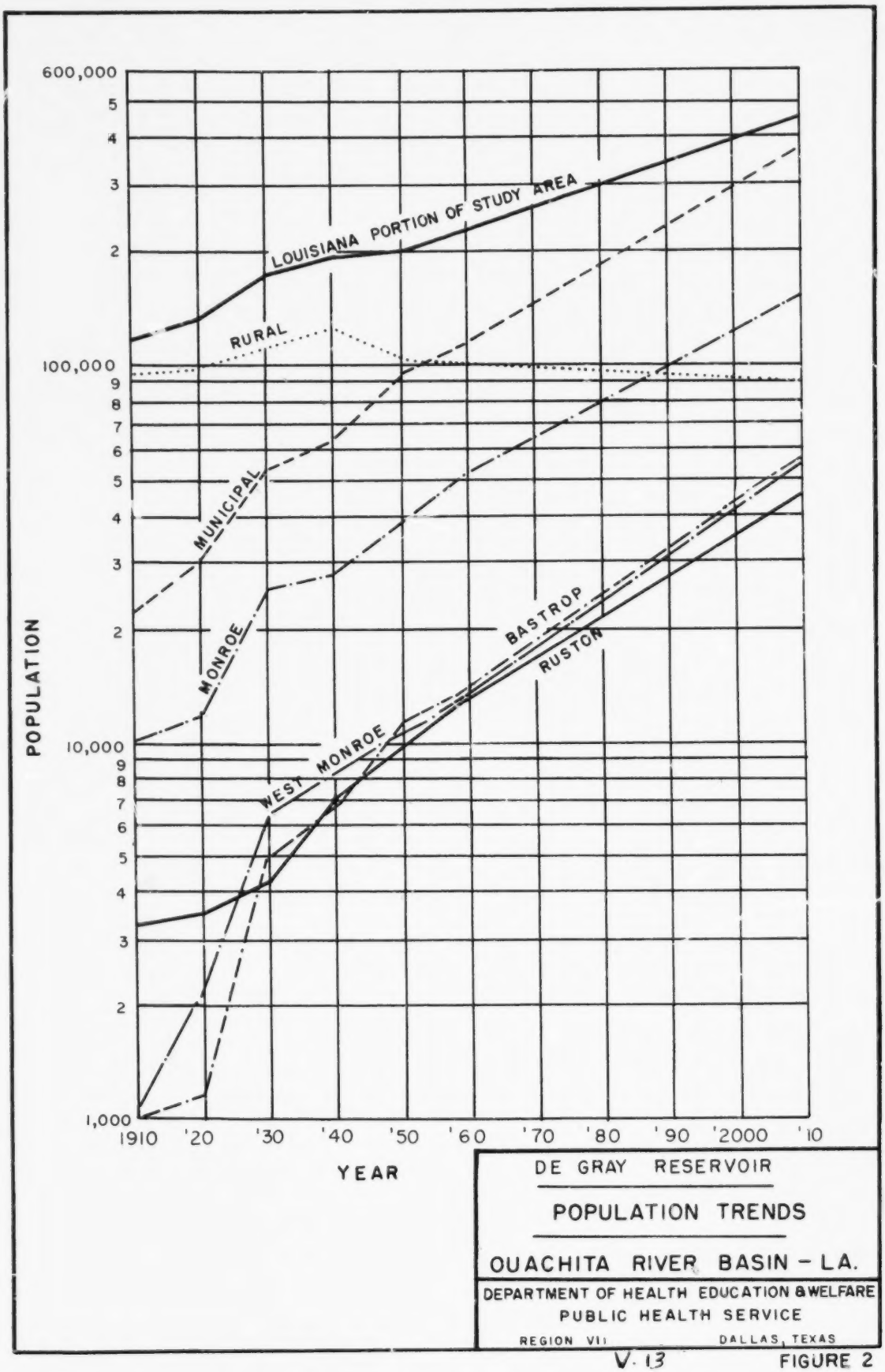
Most of the major communities have city and regional plans (which set aside sites for industrial plants) and work toward creating a favorable atmosphere for manufacturing operations. These municipalities actively promote the augmenting of their industrial bases.

Arkadelphia and Ruston are the seats of relatively small colleges (1959 enrollment was 2,000 at Arkadelphia and 3,000 at Ruston). 30/ These schools have been in part responsible for the growth of these communities and their continued growth will contribute to the projected increases in population for both of these towns.

Population Projections

The population of the study area projected to the year 2010 indicates an 83 per cent increase. Nevertheless, this projected growth will vary somewhat within the area, ranging from 63 per cent for the upper basin (Arkansas) to 100 per cent in the lower basin (Louisiana).

While rural populations will continue to shrink, ultimately leveling off at 175,000, the municipal population will more than double, reaching approximately 600,000. A great part of the municipal gain will be in the lower Ouachita River Basin, in and around the Monroe SMSA. Figure 2 for Louisiana and Figure 3 for Arkansas illustrate the projected populations of the major employment areas as well as past growth trends. It should be noted that part of the area lying in Louisiana has experienced continued growth while the Arkansas region has been declining in population since 1930.



DE GRAY RESERVOIR

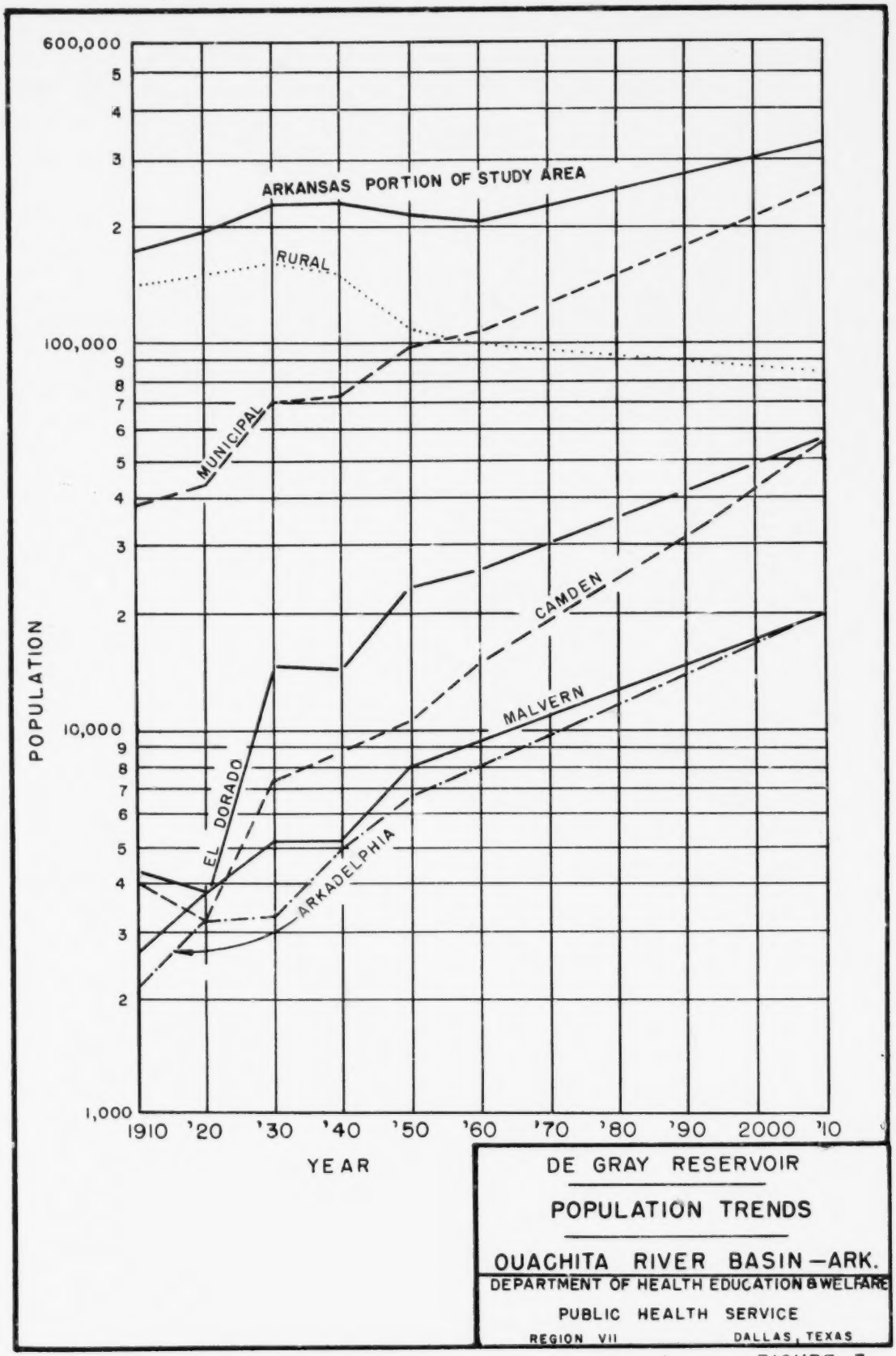
POPULATION TRENDS

OUACHITA RIVER BASIN - LA.

DEPARTMENT OF HEALTH EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

V-13

FIGURE 2



DE GRAY RESERVOIR

POPULATION TRENDS

OUACHITA RIVER BASIN—ARK.

DEPARTMENT OF HEALTH EDUCATION & WELFARE

PUBLIC HEALTH SERVICE

REGION VII DALLAS, TEXAS

FIGURE 3

VI. WATER REQUIREMENTS

The existing municipal and industrial use is shown in Table 9, along with source of supply and estimated dependable yield data.

Table 9 [6,30,31]

Present Municipal and Industrial Water Demands
Ouachita River Basin, Arkansas and Louisiana

Upper Basin - mgd

	Average Annual			Present	Approx. Firm
	Municipal	Industrial	Total	Source	Yield
Malvern, Ark.	0.8	3	3.8	Ouachita River	25 (39 cfs)
Arkadelphia, Ark.	0.9	2	2.9	Ouachita River	48 (74 cfs)
Fordyce, Ark.	0.2	-	0.2	Wells	1.5-3

Lower Basin - mgd

Camden, Ark.	1.25	14	15.25	Ouachita River	130 (200 cfs)
Crossett, Ark.	0.35	27	27.5	Wells (Sparta sand)	28
El Dorado, Ark.	3	15	18	Wells (Sparta sand)	18
Monroe, La.	6	1	7	Bayou Desired Ouachita River	6 1,000 (1,500 cfs)
West Monroe, La.	1	13.5	14.5	Wells (Sparta sand)	15
Bastrop, La.	1 (wells)	9 (wells) 28 (surface)	10 28	Wells Bayou Bartholomew	12 30
Ruston, La.	1.1	-	1.1	Well (Sparta sand)	10

In most of the municipalities per capita water requirements have increased in step with population growth. Still, the per capita water use at both Monroe and West Monroe has decreased in the last 11 years -- Monroe's from a high of 150 gpcd in 1948, to a low of 115 gpcd in 1959; West Monroe's from a high of 130 gpcd in 1950 to 50 gpcd in 1960. Both decreases are attributed by local officials to a current water metering campaign. West Monroe has recently installed meters and Monroe is presently overhauling its meters. The water served to the system in West Monroe, being highly colored, does not meet U. S. Public Health Service standards for drinking water quality. [32]

Industrial water use has remained more or less constant over the last few years.

Existing Sources

As shown in Table 9, the northern portion of the Ouachita River Basin uses surface water exclusively to meet the current municipal and industrial water requirements. There is barely enough ground water to satisfy current water demand; and with but few exceptions, this source of supply is not capable of meeting increased requirements.

The quality of surface waters in the Ouachita River upstream from Smackover Creek is very good for most purposes after the usual surface water treatment (coagulation, sedimentation, filtration, and chlorination). Smackover Creek introduces considerable oil field brine pollution into the lower reach of the Ouachita River making its quality variable. For extended periods of time the Ouachita River's chloride (Cl^-) content has exceeded the U. S. Public Health Service standard for this characteristic (250 ppm). [32] Table 1, presented earlier, discloses the Ouachita River's quality within the study area.

Ground water in the Ouachita River Basin is of variable quality. Most wells are drilled to the Sparta sand, which is found south of Camden in Union and Ashley Counties, and Union, Lincoln, Morehouse, and Ouachita Parishes. Moderate to large supplies of ground water are available from aquifers of the Sparta sand of Eocene age between depths of about 200 and 800 feet. [33,34] Table 10 contrasts the quality of ground water obtained from the aquifers in this region. The Cockfield sand overlies the Sparta sand in portions of the lower basin, yielding up to moderate amounts of water of variable quality. It is little used for municipal and industrial purposes, except in the El Dorado area of Arkansas, where the Sparta sand is being taxed to its limit. [35]

Ground water supplies of the magnitude required for pulp and paper production are limited in this part of Arkansas and Louisiana. Of the five mills presently operating, only two utilize ground water as a source of supply, although the others use some well water in minor amounts.

Table 10

Characteristics - Ground Water Sources [6,7,36]
Ouachita River Basin, Arkansas and Louisiana

	Fordyce Ark.	Crossett Ark.	El Dorado Ark.	Bastrop La.	West Monroe La.	Ruston La.
Date	4/57	4/57	10/57	11/58	4/53	9/59
Source	Wells Claiborne Sand	Wells Pliestocone Sand	Wells Sparta Sand	Wells Pliestocone Sand	Well Sparta Sand	Well Sparta Sand
pH	7.3	6.9	8.2	9.3	8.9	7.7
Alkalinity-ppm						
Phenolphthalein	0	0	0	-	-	-
Total	130.0	244.0	173	366.0	397.9	134.5
Total Solids-ppm	229.0	248.0	263	724	332	222
Hardness-ppm						
Total	99.0	240	9.0	13.3	3.9	29.3
Carbonate	99.0	0	9.0	-	-	-
Non carbonate	0	240	0			
Cl-ppm	9.0	30	26.0	167.33	18.8	19.2
SO_4-ppm	11.0	7.0	0	-	-	-
Ca-ppm	29.70	75.2	3.04	-	-	5.9
Mg-ppm	6.02	12.63	0.34	-	-	23.4
Fe-ppm	1.15	0.12	0	2.0	0.1	0.1
Mn-ppm	0.32	0.32	0	-	-	-
F-ppm	0.30	0.2	0.35	0.80	0.27	0.04
Al-ppm	-	-	-	-	-	-
Color-ppm	-	-	-	120	55	10
Depth, ft.	500	110	-	600	463	650

Additional Water Needs

Future municipal requirements are contingent upon industrial growth; therefore, it is assumed that industrial water will be available to support the industrial expansion possible in the Ouachita River Basin, under either of the water supply situations previously described.

Upper Ouachita River Basin

The projected water requirement in the upper Ouachita River Basin (above Camden) is approximately 21 mgd (average). This is divided as shown in Table 11.

Table 11

Projections-Municipal and Industrial Water Demands-2010
Upper Ouachita River Basin-Arkansas

Municipal Area	Projected Population	Municipal Demand	Industrial Demand	Total
Malvern	20,000	3 mgd	6 mgd	9 mgd
Arkadelphia	20,000	3 mgd	6 mgd	9 mgd
Fordyce	8,000	1.2 mgd	1.8 mgd	3 mgd

The Ouachita River, which is the present source of municipal and industrial water supply for the Malvern and Arkadelphia areas, has sufficient flow to provide adequate quantities of satisfactory quality water to meet the projected requirements through the year 2010. Likewise, at Fordyce, indications are that ground water and/or local impoundments will be capable of meeting the projected municipal and industrial demand.

Lower Ouachita River Basin

Water supply is the key to future development of the lower Ouachita River Basin. Two water supply situations, previously described, must be considered in projecting water demands for this portion of the study area and determing the requirements, which exceed the existing sources of supply.

In this area, two industries presently flourish and exert significant water demands. These are pulp and paper and petrochemical production. The development of these industries, in no small way, will affect the population in the lower basin - hence, the municipal

water demands. In addition, the Ouachita River's waste (municipal and industrial) assimilating capacity will play a major role in development of this part of the study area's water demand. This is by no means unique, yet the complexities of the conditions regarding stream flow in the lower Ouachita River Basin dictate that these seemingly separate requirements be projected as one indivisible demand. The segments are discussed individually in order that various parts of the total demand can be more clearly defined.

Camden Area
Industrial Water Demand - Benton and DeGray Projects
(Water Supply Situation No. 1)

The most significant water demands for the lower Ouachita River Basin are projected for the pulp and paper industry in the Camden area. For the purposes of this study, it is assumed that a large segment of that industry will develop in this area. This assumption is substantiated by the previous discussion of resources available in this area. In addition to its central location, with respect to timber resources, this general location is favorable with respect to economical transportation of industrial output afforded by the 6.5-foot Ouachita River navigation channel which connects Camden directly with the Mississippi River and the Gulf Coast.

Based upon statewide pulp and paper production projections (which are in turn founded on projected National demands and regional resources), the 2010 demand for water by this industry, in Arkansas, will be 290 mgd (more than four times the current demand of 70 mgd). 6/ This demand is predicated on projected 2010 output of 8,300 tons/day using 5.3 million cords per year.

Utilizing current operations (in Arkansas) as a basis, approximately 105 mgd will be required to meet the 2010 projected output in this area of 3,000 tons/day. Although this is a large portion of the 290 mgd statewide projected need, the expected timber resource development will be capable of providing the cordwood needed.

Existing processes require from as little as 18,000 gallons to more than 100,000 gallons per ton of production. In 1957, Arkansas' paper industries required about 35,000 gallons per ton (13,500 gpd per employee or 20,000 gallons per cord using 1.75 cords per ton). This compares well with Louisiana's operations for 1955, when 122 mgd was required to produce 1.6 million tons (4,400 tons/day) or 28,000 gallons per ton. (Louisiana's forests border similar stands of timber in Arkansas.) 6,37/

The expected industrial water needs for this area assume limited production expansion in one of the two paper mill areas now using ground water in their processes. It is quite possible for the Crossett area to expand by taking water from either the Saline or Ouachita Rivers as the pumping distance from either is eight or nine miles. Large growth of this industry at Pine Bluff depends upon the quality of the Arkansas River improving a considerable degree; however, the river presently affords a good waste disposal media but its quality precludes many other uses.

Should the proposed Benton project be constructed and placed in operation as detailed in a previous report, the Saline River would serve the projected municipal and industrial water needs for the Warren and Crossett areas.

Camden Area
DeGray Project Only
(Water Supply Situation No. 2)

Inasmuch as the Benton Reservoir is still in the study stage and therefore not authorized for construction, alternate water requirements for the lower Ouachita River Basin have been determined, assuming that this reservoir will not be constructed. 38/

In the absence of adequate flow in the Saline River Basin, the pulp and paper production facilities will locate quite differently from the previously described developments. The Camden area would play an even greater role by having to provide production facilities for a larger raw material harvesting area.

Based upon the anticipated production potential of this area of 4,580 tons per day (2.9 million cords/year) and 35,000 gallons per ton, the projected pulp and paper industry demand in the Camden area will be 160 mgd in 2010. Total current demand in the northern portion of the lower basin is 43 mgd for production of 1,255 tons/day (Camden and Crossett).

Emphasis is being placed upon pulp and paper industry water demands in the Camden area since conditions in that reach of the Ouachita River Basin favor buildup of this class of industry. There are, however, other demands for water supply to be met in the lower basin -- those exerted by other industries and municipalities.

Other Industrial Water Demands

The situation downstream from Camden is very favorable to continued growth, specifically connected with petroleum processing, chemical and petrochemical manufacture, and pulp and paper production, provided adequate water supply is available.

The water demands are spread out throughout the river valley. The industries (and municipalities) in the area below Camden have, to date, relied upon ground water to meet their demand. This can be attributed to the relative abundance of high quality well water. Furthermore, the Ouachita River is unsuitable for most uses downstream from Smackover Creek, even though it has considerable flow.

Brine entering the Ouachita River via Smackover Creek increases in chloride content so that it exceeds the U. S. Public Health Service standard (250 ppm) and is quite corrosive. Thus, at present, ground water is expected to serve as the source of supply for El Dorado and Crossett, Arkansas, and West Monroe, Ruston, and Bastrop, Louisiana.

El Dorado is one of the rapidly expanding industrial centers of Arkansas. Most of the refining and petrochemical industry in the State is located within or near this city. Expansion is presently hampered by the unavailability of a suitable water supply. Projections indicate an increase of the industrial water requirements in this area within the next fifty years. Although some degree of diversification can be expected, expansion of the existing petroleum and petrochemical industry is anticipated. Based upon known reserves and projected trends, industrial water demands for the El Dorado area should approach 60 mgd. Since the existing ground water source is presently taxed to its limit, the Ouachita River could satisfy the additional water requirements.

Additional industrial water demand is expected in the Monroe-West Monroe area as the result of growth of the pulp and paper and petrochemical industries. However, the flow of the Ouachita River appears to be far in excess of anticipated demands in this area. Stream quality is the major consideration affecting demand at this point on the stream. At present, the stream's chloride content renders it unsuitable for many industrial uses, other than cooling, for considerable periods of time.

In the Bastrop area, northeast of the Monroe area, the quality of water in Bayou Bartholomew is satisfactory for use in pulp and paper manufacture; however, the stream's firm yield is limited -- 40 cfs (27 mgd) during 1956. 6,37/ Nevertheless, the paper mill at Bastrop maintains an "upland" reservoir which yields more than enough water for present operations and some expansion. (An "upland" reservoir is a water storage facility located off the stream. Water from the stream

is pumped from the stream into the reservoir during times of relatively high flow and is withdrawn during times of low flow. Costs vary with site applicability and pumping expenditures.) Additional storage of this sort could be provided to meet future demands (if and when these demands materialize in the Bastrop area, which is five to seven miles from the Ouachita River).

A tabulation of the lower Ouachita River Basin's projected industrial water demand by area is shown in Table 12.

Municipal Water Demand

Projections of water requirements for municipal use are based on population growth patterns and considerations of the present and past water demand of the area. Municipal water demand includes the requirements which would be met by a public water supply system. Furthermore, these demands can be said to vary according to population served. This is in contrast to industrial demands which are considered to vary according to product output - for example, in the pulp and paper industry, to the tonnage output (and pulping process utilized).

Expectations are that municipal demands for water on a per person basis will increase as the population served expands. This growth of municipal demand is attributed to the local production of more goods and services to satisfy local needs. Variations in municipal demands are illustrated in the appendix to this report (Exhibit A). The projected municipal demands shown in Table 12 (and Table 11, the upper basin) represent the quantity of raw water which must be delivered to the treatment plants. It includes distribution system losses, unaccounted for water, and treatment plant attenuation.

Stream Quality Maintenance

Protection of the quality of Arkansas' water is primarily the responsibility of the Arkansas Water Pollution Control Commission; while the protection of the quality of Louisiana's waters is the responsibility of the Louisiana State Board of Health and Louisiana Stream Control Commission. Stream quality criteria and subsequent regulations governing waste discharges, and other pronouncements on the maintenance of water quality within the boundaries of Arkansas and Louisiana, come from these agencies. The use of water will almost inevitably result in the production of some liquid wastes which, even after a high degree of treatment, will degrade the quality of the receiving stream. It is essential that recognition be given to the need for flows which must be maintained in the receiving stream if the quality of its waters is to be kept at reasonable levels. Therefore, estimates of these stream flow needs have been made since they are an inseparable part of the water demand from a reservoir if unimpounded

Table 12

Projected Municipal and Industrial Water Demand, 2010
Lower Ouachita River Basin, Arkansas and Louisiana

Municipal Area	Projected Population	Municipal Demand	Industrial Demand	Total M & I Demand
Camden, Ark.	55,000	10 mgd	105 mgd* 160 mgd**	115 mgd* 170 mgd**
El Dorado, Ark.	58,000	10 mgd	60 mgd	70 mgd
Monroe La.	162,000	30 mgd	110 mgd	140 mgd
West Monroe, La.	55,000	10 mgd	70 mgd	90 mgd
Bastrop, La.	55,000	10 mgd	70 mgd	90 mgd
Ruston, La.	45,000	7 mgd	3 mgd	10 mgd

*Water Supply Situation No. 1
**Water Supply Situation No. 2

flows in the stream have insufficient assimilative capacity. Although the final determination and acceptance of stream quality must come from the responsible agencies in Arkansas and Louisiana, it is believed that the maintenance of stream flows at the levels indicated will result in quality conditions reasonably acceptable to them.

The municipal waste treatment picture in the Ouachita River Basin has undergone considerable change in the last four years. Since 1956-57, the percentage of the sewered population for which adequate sewage treatment is provided has jumped from 35 per cent to 72 per cent (this figure includes the Saline River watershed, tributary to the Ouachita River Basin). 39/ Three of its largest municipalities, Camden, Arkansas; Monroe and West Monroe, Louisiana, do not provide treatment of their wastes before release to the Ouachita River.

Oil fields, refineries, and pulp and paper mills comprise the major sources of pollution in the basin. Fish kills and other manifestations of overloading of the stream's waste assimilation capacity have been observed, beginning in the 1940's. Natural pollution during receding flood flow is extensive in the reach from mile 223 (Alabama Landing) up to mile 308 (Champagnolle Creek), being associated with the runoff from forest litter imparting oxygen demand to the water. 40/ Runoff from forest litter also imparts color to the stream in the lower reaches.

For some time, damages occurred in the upper basin due to the discharge to the river of sulfuric acid at Magnet Cove and Malvern. This condition results from drainage contact with pyrites and lignites uncovered during barite strip mining operations. Further occurrence has been curtailed by backfilling and other methods of segregating runoff from the acid formation areas. Also, the small amount of alumina reduction waste is treated prior to discharge to the Ouachita River.

The projected waste loading in the upper reaches of the Ouachita River should be easily assimilated and will probably be completely stabilized before reaching the Camden area, some 70 miles downstream from Arkadelphia. This projection is predicated upon a minimum of secondary treatment being given all wastes, i.e., substantially complete removal of all floatable or settleable solids, 85 - 90 per cent removal of biochemical oxygen demand (BOD) and maximum removal or neutralization of all toxic or deleterious substances.

"Oxygen sags" -- the result of loading a stream with BOD -- have occurred in the Ouachita River below its junction with the tributary which carries the waste discharge from the paper mill at Camden, 2/ and below its junction with the tributary which carries the waste from the paper mill at Crossett. A rather extensive fish killing took place during the late 1940's near the Arkansas-Louisiana State

line which was attributed to oxygen depletion below the Crossett paper mill discharge to the Ouachita River. Minor kills since that time have been recorded in that area and farther downstream. This situation can usually be attributed to overloading of the stream's BOD assimilating capacity. The industrial waste treatment at the Camden and Crossett paper mills has been stepped up so that, at present, this condition is uncommon (90 per cent BOD removal being obtained by treatment).

Brine Pollution Control

The Arkansas Water Pollution Control Commission in General Order No. 1-59 set up a plan to abate oil field brine pollution in stages. It is planned that total abatement will be effected not later than June 30, 1964. 41/ All crude oil producing operations will be required to reinject their salt brine or dispose of it so that there will be no discharge to any watercourse. This will materially reduce chloride concentrations in the tributaries to the Ouachita River which traverse Arkansas' oil fields, particularly Smackover Creek. This program will substantially lower the most objectional pollutant entering the Ouachita River above the Arkansas-Louisiana State line ... salt (NaCl and other chloride salts). Louisiana's pollution control agency is working also toward this goal for the lower reaches of the basin. Although the Arkansas cleanup campaign is only a bit over 40 per cent complete timewise (a little more than two years of five have elasped), reports are that the salt load has been reduced by almost 50 per cent. Releases of brine pollution are now prohibited in new operations and it is expected that the existing manmade brine pollution will be eliminated in the foreseeable future.

With this accomplished, the Ouachita River will be as desirable a source of water for municipal and industrial purposes in its lower reaches as in its upper portion, provided that its other qualities are not permitted to deteriorate.

Stream Quality Maintenance Requirements

Maintenance of a stream flow of sufficient volume to assimilate treated wastes without impairment of water quality is essential for optimum use of water resources of an area. It will be necessary to supplement stream flows below the reservoir by releases from it to assure stream quality at a level that will place no restrictions on water use and maintain an acceptable environment for aquatic life.

The flow characteristics of the stream -- whether it runs deep or shallow, fast or slow, smooth or broken -- coupled with its temperature, determine for the most part, its BOD assimilating capacity. Stream temperatures are available for the Ouachita River in this region. 5/ The self-purification capacity of a watercourse

can be determined best through detailed sampling and analysis. Since these data are not available, assumptions were made, based on experience on streams of similar character.

The Ouachita River between Camden, Arkansas, and Columbia, Louisiana, is a slowly moving body of water held at a fairly uniform level by a system of six locks and dams (which provide a 6.5-foot navigation channel) during most of the year. These structures impede the stream's velocity and hence its reaeration rate. This rate is probably one-half of what it would be in the absence of these restrictions. In effect, each dam produces a stilling reservoir, thus curtailing agitation and reaeration. In addition, brine stratifies behind lock and dam No. 8, just below Smackover Creek. 42/ This results in slugs of high chloride concentration being thrust upon downstream users (or potential users) during flush-outs. Table 13 shows the fluctuations in the water quality downstream from the waste discharges originating in Arkansas. The wide variation in quality is, in the main, a function of the lock and dam setup on the Ouachita.

Assuming that minimum of secondary treatment will be provided for all projected waste flows before release, the critical reach of the Ouachita River, with respect to oxygen balance, would be downstream from the Camden, Arkansas area. This is based on the projected expansion of the pulp and paper industry in this part of the basin. Waste assimilation requirements have been derived based upon the two water supply situations previously detailed.

The average BOD (5 day) loading of Kraft paper production is 50 pounds or a P. E. (population equivalent) of 300 per ton of product. 44/ If the Benton project were to be constructed, the projected population loading from the pulp and paper wastes in the Camden area would be equivalent to a population of 900,000. Since existing treatment processes can achieve 90 per cent removal of BOD from this type of waste, the total discharged waste load is assumed to be equivalent to a population of 90,000. The population equivalent of the municipal wastes should be added to this ... 53,000 assumed before treatment or 5,300 discharged to the stream after treatment. Total projected population equivalent for the area is assumed to be 95,300.

Based on this waste loading and other assumed conditions in the stream, the minimum mean monthly flows at Camden to meet the total municipal and industrial water supply needs of this area as well as maintaining at least 4.0 ppm downstream, range from as low as 235 cfs to as high as 865 cfs. A tabulation of the requirements and assumption is shown in the appendix to this report (Exhibit B), together with the assumptions for stream flow, temperature, and other considerations in order to derive the required quantities of waste assimilation water under these conditions. As shown in that tabulation, if assimilation of biochemical oxygen demand were the only considerations, the

Table 13

Chemical Characteristics-Ouachita River [43/]
Upstream from Monroe, Louisiana
1959

Date Coll.	Temp. °C	Diss. O_2	% Sat.	pH	Turb.	Tot. Alk. as $CaCo_3$ (ETDA)	Tot. Hard.	Color	So-dium	Potas-sium	Spec. Con. micromohs at 25°C	Iron	Chloride
Jan.													
A.	3	11.5	85	6.8	30*	17	99.2	20	108	5.5	1286		220
B.	9	12.2	105	6.8	30*	20	75.2	20	93	7.5	919	----	156
Feb.													
A.	7	10.9	89.5	6.8	32*	20	67.2	25	110	8	857	----	133
B.	12	8.0	73.8	6.5	40	12	48.8	50	108	8	612	----	10.7
Mar.													
A.	12	7.8	72.0	6.5	30	12	26	50	60.5	6	207	----	31
B.	14	7.1	68.5	6.4	30*	14	36	40	65	8.5	330	----	159
Apr.													
A.	20	5.8	63.3	6.2	30*	14	48.8	40	74.5	8.3	428	----	68.1
B.	18	6.4	67.2	6.6	30*	20	54	30	84	10	585	----	90.4
May	25	4.2	50.2	6.5	30*	18.2	43.6	40	73	7.0	380	----	65
June	27	6.4	79.7	6.9	30*	28	186	30	171	13.2	1786	----	478
July	29	5.0	64.3	6.6	35*	28.4	58.8	65	73	7.5	441	----	89.3
Aug.	31	5.8	77.6	6.7	30*	24.6	94.8	30	121	4	791	----	199.1
Sept.	30	6.6	86.6	6.9	32*	28	99.6	18	144	4.1	543	----	211.5
Oct.	27.0	7.3	91.0	7.1	30*	27.0	108.4	20	186.0	6.0	659.0	----	239.0
Nov.	20.0	8.0	87.1	7.1	30*	40.0	92.0	20	114.0	6.5	635.0	----	161.3
Dec.	11.0	10.3	93.2	6.8	30*	37.0	102.0	20	135.0	7.0	736.0	----	188.5

* Less than

A.--Sample collected between 1st and 15th of month.
B.--Sample collected between 16th and 31st of month.

proposed project would need to provide storage to yield 87 mgd, to augment existing minimum flow during June, July, August, September, and October. There are, however, other characteristics of paper mill wastes to be considered.

Minimum flows at Camden to maintain 4.0 ppm dissolved oxygen below that point will range from 50 cfs during the cooler part of the year to 680 cfs during June, July, and August, the hot months. Water temperatures vary from a low of 49°F to a high of 87°F ... average 68°F. The resulting annual average flow required would be 335 cfs (220 mgd) ... much less than the 2,292 cfs minimum annual mean flow, but much more than the minimum monthly average flow of 200 cfs. Thus, there will be times during the year when waste assimilation flow requirements will exceed the Ouachita River's discharge in this area. Projected oxygen demand (in the treated municipal and industrial wastes) will be greater than assimilating capacity during June, July, August, September, and October. The annual average augmentation flow would be 87 mgd to meet the waste assimilation deficit in this area.

The color of paper mill waste which would be carried into the stream is of equal or perhaps greater importance than the oxygen demand loading. While color in water has little sanitary significance, it is undesirable aesthetically and may stain materials or adversely affect some industrial processes. Pulp and paper production requires water which contains no more than 25 ppm of color (Kraft paper, bleached). 45/ And, today's public demands a sparkling, clear water. Modern water treatment processes can reduce color from as high as 150 ppm to the U. S. Public Health Service acceptable standard of not more than 20 ppm. 32,45/ Nevertheless, the cost of color removal at the upper limit is considerable.

The Ouachita River now has a natural color, caused by runoff from forest litter, etc., of about 30 ppm in the Camden area. Paper mill wastes have a color of approximately 250 ppm. While considerable time and effort have been spent in developing treatment for pulp and paper wastes, existing systems are incapable of reducing the color at a reasonable cost. 46/ Nevertheless, this pollutant must be removed before the water can be used. A reasonable level of color must be maintained in the stream if the stream's usefulness is not to be unduly diminished. A maximum color of 75 ppm in the stream in this area has been assumed as the criterion, as the result of several conferences with officials of the water pollution control agency of Arkansas.

Appearances are that there is some reduction (perhaps by absorption) in color when a quantity of paper mill wastes is mixed with the waters of a stream containing a similar type of color, such as that produced by forest litter, in lesser quantity. There does not seem to

be, at the moment, any method available for predicting this reduction. Assuming a color of 250 ppm in the waste, 30 ppm in the Ouachita River and the 75 ppm criterion for the mixture, it will require about 600 cfs (400 mgd) to assimilate the color in this waste to an acceptable level (See Appendix.).

The combined projected municipal, industrial, and waste assimilation water requirements exceed the anticipated monthly mean stream discharges for the period extending from June through November in the Camden area by an annual average of approximately 130 mgd (200 cfs). Additional study, as the industry develops would be required to bear this out. Conditions could develop which would seriously curtail growth of the pulp and paper industry in this area due to the inability of the Ouachita River to assimilate the waste loading (color or organic). The provision for 200 cfs (130 mgd) waste assimilation flow should forestall this eventuality. Full development of the municipal and industrial demand is contingent upon adequate waste assimilation flow being provided.

In the absence of the proposed Benton project, the proposed project under consideration would be called upon to serve the total water supply needs of the alternative projections for the critical demand area. Tabulation of the factors considered and flow requirements are contained in the Appendix to this report.

Based upon the assumption detailed earlier, the projected pulp and paper industry would release waste with an estimated population equivalent of 137,500 after 90 per cent removal of BOD. When the projected population loading of the equally treated municipal wastes projected for the Camden area is added, a total population equivalent of 143,000 is assumed to be released to the Ouachita River in this area. As with the previous water supply assumption, if only BOD assimilation is to be regarded, storage to yield an annual average of 218 mgd will be needed to accommodate the projected development.

Less than this would be needed if the waste releases were spread out down the basin. While this would reduce the requirement with respect to BOD assimilation, the color problem would still require a significant flow to reduce this characteristic to the tolerable level of 75 units. As before, color assimilation must also be considered in determining the total water demands for the Camden area and are shown in detail together with other essentials in the Appendix. Under the worst conditions, assuming a single waste discharge in the Camden area, additional flow averaging 280 mgd would be needed.

Total water demands for the Ouachita River are illustrated in Table 14.

Table 14

Projected Water Requirements - 2010
In Excess of Existing Source Yields
Ouachita River Basin, Arkansas and Louisiana

Area	Projected M & I Demand (mgd)	Projected Waste Assimilation Requirements (mgd)	Firm Yield Available Source (mgd)	Projected Additional Requirements (mgd)
Arkansas				
Malvern	9	*	25	None
Arkadelphia	9	*	48	None
Fordyce	3	*	1.5-3	1.5-None
Camden	115**	520-560****	200 cfs	130****
	170***	480-830****		280****
El Dorado	70	*	18	52
Louisiana				
Monroe	140	*	1,000	None
West Monroe	10 (municipal only)	*	1	9
Bastrop	10 (municipal only)	*	3	7
West Monroe)	70 (industrial)	*	1,000	None
Bastrop)			30	
Ruston	10	*	10	None

* Not Significant
** Assuming Water Supply Available from both Benton and DeGray
*** Assuming Water Supply Available from DeGray only
**** See Appendix for details

Plan for Supplying Future Requirements

The existing sources of supply are already taxed to their fullest at El Dorado, Arkansas, and Monroe, Louisiana. In these areas, future growth is contingent upon additional quantities of suitable quality water being obtained. At present, neither of these areas can use the Ouachita River as a source of supply for extended periods due to its high chloride content. Upon successful completion of the Arkansas Water Pollution Control Commission's oil field brine cleanup, the Ouachita River should be satisfactory for most municipal and industrial uses following standard treatment in a rapid sand filter plant.

There is not a single impoundment or series of impoundments available at reasonable cost in the El Dorado area to meet the projected demands. The Ouachita River offers the most feasible source of supply provided that its quality is maintained after the oil field brine pollution is abated.

With maintenance of the Ouachita River's quality, the projected demands for Camden, Monroe, West Monroe, and possibly Bastrop can be met from the stream's main stem flow.

After the oil field brine pollution is abated, the quality of water all along its course should be of satisfactory quality for municipal and industrial use. Under the conditions of Water Supply Situation No. 1, the indicated annual average release of 130 mgd from the proposed project will provide for the total water supply needs of Ouachita River Basin. Similarly, with Water Supply Situation No. 2, an annual average release of 250 mgd will provide for the projected water supply needs under those conditions. Furthermore, the controlled flow conditions resulting from reservoir operations could result in reduced color below the existing level (average 30 ppm) at Camden. In this way water can be withdrawn, treated and used. The treated waste can then be returned to the stream for downstream use.

There does not appear to be an alternative to this plan which even approaches feasibility. The cost of transmission alone (not including impoundment) from alternative sources yielding water in adequate quantities and of satisfactory quality would exceed the cost of transmission from the Ouachita River.

VII. BENEFITS OF STORAGE

The alternative cost method employed in determining the benefits from this project is essentially based on the question, "What will be provided to meet the water requirements of the area in the absence of the project under consideration, and -- how would the cost of obtaining water from this source compare with that for transmitting and treating water from the project?" Since there is no other source available which would not incur considerable transmission costs, the most likely alternative source to the proposed project would be a single-purpose project at the DeGray site.

It seems certain that the expanded need and use of water for municipal and industrial purposes forecast in the preceding portions of this report will not materialize in the absence of suitable water supply. The area population growth, likewise, will probably be less than expected. Furthermore, the full industrial expansion projected cannot be achieved without the waste assimilation water being provided to maintain stream quality as required by the pollution control agencies of Arkansas and Louisiana. Evaluation of benefits of storage must be tempered in the light of these considerations.

Alternative Plan

The most likely alternative source to the proposed project is a single-purpose reservoir at the same site. Other sites are available, but they would not yield the quantity of water required. All are on tributaries to the Ouachita River. Since the project and its alternative are at the same site, there will be no difference in treatment or transmission cost to be considered.

Water Supply Benefits

The projected municipal and industrial utilization of this stream is contingent upon maintenance of its quality at a satisfactory level for these uses (after abatement of the existing oil field brine pollution). Various plans for water quality maintenance were considered, such as treatment and storage with controlled release. Still, the dominating pollutant -- the most troublesome constituent -- is not BOD, solids, or sulfates, but color concentration. This characteristic of paper mill waste is extremely difficult to control and costly to remove by treatment. Recently, however, advances have been made in color removal from certain classes of paper mill wastes.

As previously pointed out, the Ouachita River's color assimilation capacity could limit the basin's development. The water required for waste (color) assimilation is therefore an operating need equal to the water for municipal and industrial purposes. Water supply for the total projected requirements could be provided from storage in the proposed project.

Water Supply Situation No. 1 47/

The net investment in the alternative reservoir is estimated at $12,000,000, including interest during construction. Estimated annual operation and maintenance charges would amount to $100,000. Based upon a non-Federal interest rate of 4 per cent and an economically useful life of 50 years, the equivalent series of annual payments would be $558,600. Thus, based upon the cost (including maintenance and operation) of the most likely alternate source, a single-purpose dam at the proposed DeGray site, storage provided in the proposed DeGray project for a firm annual yield of 130 mgd of water supply would have an annual benefit of $658,600.

Water Supply Situation No. 2

While two water supply situations have been considered throughout this report, the water supply needs of the area to be served by the proposed DeGray project should receive precedence, because this project is authorized and nearing the construction stage. 38/ Water supply benefits ascribed to this project have been determined under this condition. In the absence of a firm commitment regarding the Benton project, it is concluded that water supply demands and benefits attainable under the assumptions of water supply situation No. 2 should take precedence.

The net investment in the alternative reservoir is estimated at $16,960,000, including interest during construction. Estimated annual operation and maintenance charges would amount to $120,000. Based upon a non-Federal interest rate of 4 per cent and an economically useful life of 50 years, the equivalent series of annual payments would be $789,000. Thus, based upon the cost (including maintenance and operation) of the reasonable alternative, a single-purpose dam at the proposed DeGray site, storage in the proposed project to provide a firm annual yield of 250 mgd (all that will be available from the proposed project) for water supply would have an annual benefit of $909,000.

VIII. BIBLIOGRAPHY

1. Federal Security Agency, Public Health Service, "Report on Water Pollution, Ouachita River Basin," unpublished, 1952.

2. U. S. Army Engineer District, Vicksburg, Mississippi, Review Report, DeGray Reservoir, Caddo River, Arkansas, 5 April 1957, revised 18 April 1958, and DeGray Design Memorandum No. 1, Hydrology and Hydraulic Analysis, November, 1960.

3. U. S. Geological Survey Water Supply Paper 1561, Surface Water Supply of the United States, 1958, Part No. 7, Lower Mississippi River Basin, U. S. Government Printing Office, Washington, 1960.

4. U. S. Army Engineer District, Vicksburg, Mississippi, enclosure with a letter dated 1 November 1960, addressed to Water Resources Section, U. S. Public Health Service, Region VII, Dallas, Texas.

5. U. S. Geological Survey Water Supply Papers 1352, 1402, Quality of Surface Waters of the United States, 1954, 1955, Parts 7 and 8, Lower Mississippi River Basin and Western Gulf of Mexico Basins, U. S. Government Printing Office, Washington, 1959.

6. Noel H. Wood, Arkansas Water Resources, University of Arkansas, College of Business Administration, Industrial Research and Extension Center, Little Rock, June, 1959.

7. Arkansas State Board of Health, Bureau of Sanitary Engineering, Chemical Data on Arkansas Public Water Supplies, 1958.

8. U. S. Army Engineer District, Vicksburg, Mississippi, enclosure with a letter dated 18 August 1961, addressed to Water Resources Section, U. S. Public Health Service, Region VII, Dallas, Texas.

9. U. S. Department of the Interior, Bureau of Mines, Minerals Yearbook(s), 1954 through 1959, Washington.

10. Oil and Gas Journal, Review and Forecast Issue, January 25, 1960.

11. Southern Forest Survey Progress Reports, Preliminary Forest Statistics for Southwest Arkansas Counties, Forest Service, U. S. Department of Agriculture, New Orleans, 1959.

12. Forest Survey Release 75, Forests of Louisiana, 1953-54, Forest Service, U. S. Department of Agriculture, New Orleans, April, 1955.

13. Southern Forest Experiment Station, Pulpwood Production in the South, 1946, 1959, Forest Service, U. S. Department of Agriculture, New Orleans.

14. U. S. Department of Commerce, Bureau of the Census, Census of Agriculture, Arkansas, 1950, 1954.

15. U. S. Department of Commerce, Bureau of the Census, Census of Agriculture, Louisiana, 1950, 1954.

16. U. S. Department of Commerce, Bureau of the Census, Census of Manufactures, Arkansas, 1947, 1954, 1958.

17. U. S. Department of Commerce, Bureau of the Census, Census of Manufactures, Louisiana, 1947, 1954, 1958.

18. U. S. Department of Commerce, Bureau of the Census, Census of Business, Retail, Arkansas, 1948, 1954, 1958.

19. U. S. Department of Commerce, Bureau of the Census, Census of Business, Retail, Louisiana, 1948, 1954, 1958.

20. U. S. Department of Commerce, Bureau of the Census, Population Census, 1930, 1940, 1950, 1960.

21. Public Health Service, Region VII, Dallas, Texas, "Municipal and Industrial Water Requirements, Benton Reservoir, Saline River, Arkansas," in cooperation with the U. S. Army Engineer District, Vicksburg, Mississippi, November, 1960.

22. Arkansas-White-Red Basins Inter-Agency Committee, Arkansas-White-Red River Basins Part II, Section 16, Minerals and Geology, 1955.

23. U. S. Geological Survey, Howard L. Conklin, Water Requirements of the Aluminum Industry, Water Supply Paper 1330-C, U. S. Government Printing Office, Washington, 1956.

24. Interview with officials of Magnet Cove Barium Company and National Lead Company, Bariod Division, Arkadelphia, Arkansas, by representatives of U. S. Public Health Service, Region VII, September, 1960.

25. Forest Service, Timber Resources for America's Future, Forest Resource Report No. 14, U. S. Department of Agriculture, Washington, January, 1958.

26. Southern Forest Experiment Station, Forest Service, Timber Supplies for Industry in Arkansas, Forest Resource Report No. 11, U. S. Department of Agriculture, Washington, 1956.

27. U. S. Department of Commerce, Bureau of Census, Statistical Abstracts of the United States, 1958, Washington.

28. 1957 Directory of Arkansas Industries, University of Arkansas, Industrial Research Center, Arkansas Industrial Development Commission, Little Rock (revised to April, 1960).

29. State Department of Commerce and Industry, Directory of Manufactures, Baton Rouge, 1959.

30. Interviews with Chambers of Commerce and municipal officials and/or water works personnel at Malvern, Arkadelphia, Camden, El Dorado, Crossett, Fordyce, and Warren, Arkansas; and Bastrop, Ruston, Monroe, and West Monroe, Louisiana, by representatives of the U. S. Public Health Service, Region VII Office, Dallas, 1960.

31. Interviews with industry officials at Malvern, Arkadelphia, Camden, El Dorado, Crossett, Fordyce, and Warren, Arkansas; and Bastrop, Ruston, Monroe, and West Monroe, Louisiana, by representatives of U. S. Public Health Service, Region VII Office, Dallas, 1960.

32. Public Health Service Drinking Water Standards - 1946, U. S. Department of Health, Education, and Welfare, U. S. Government Printing Office, Washington, 1960.

33. A. N. Turcan, Jr., Ground Water Conditions in Union Parish, Louisiana, U. S. Geological Survey, undated.

34. Data transmitted with letter dated October 21, 1960, from A. N. Turcan, Jr., Acting District Geologist, U. S. Geological Survey, Baton Rouge, Louisiana, to Water Resources Section, Public Health Service, Region VII, Dallas, Texas.

35. R. C. Baker, U. S. Geological Survey, Arkansas' Ground-Water Resources, Water Resources Circular No. 1, State of Arkansas Geological and Conservation Commission, Little Rock, 1955.

36. Unpublished chemical analysis transmitted to Water Resources Section, Public Health Service, Region VII, Dallas, Texas, by Northern Regional Office, Louisiana Department of Health, Monroe, October 4, 1960.

37. Louisiana Department of Public Works, Water, A Special Report to the Louisiana Legislature, Baton Rouge, 1956.

38. U. S. Army Engineer District, Vicksburg, Mississippi, letter dated 12 June 1961 to Water Supply and Pollution Control, Public Health Service, Region VII, Dallas, Texas.

39. Carl C. Thompson, "The Man on the Bank," Southwest Water Works Journal, Vol. 42, No. 9, Temple, Texas, December, 1960.

40. U. S. Public Health Service in cooperation with Arkansas Game and Fish Commission, Fish Kill in the Ouachita River Near Alabama Landing, Louisiana, Occurring During a Period of Receding Flood Waters, undated.

41. Arkansas Water Pollution Control Commission, General Order No. 1-59, dated 29th day of June, 1959.

42. Public Health Service, Arkansas-White-Red Field Studies, Ouachita River, Environmental Health Center, Cincinnati, August, 1953.

43. Louisiana Wild Life and Fisheries Commission, 1958-59, Eighth Biennial Report, New Orleans, 1960.

44. Willem Rudolphs, Industrial Wastes - Their Disposal and Treatment, ACS Monograph No. 118, Reinhold Publishing Corp., New York, 1953.

45. Babbitt and Dolan, Water Supply Engineering, McGraw-Hill Co., Inc., New York, 1955.

46. Albert J. Herbert and Herbert F. Berger, A Kraft Waste Color Reduction Process Intergrated with the Recovery System, National Council for Stream Improvement, unpublished (presented at 1960 Purdue Industrial Waste Conference).

47. U. S. Army Engineer District, Vicksburg, Mississippi, letter dated 19 June 1961 to Water Supply and Pollution Control, Public Health Service, Region VII, Dallas, Texas.

IX. APPENDIX

EXHIBIT A

VARIATIONS IN MUNICIPAL WATER DEMAND
OUACHITA RIVER BASIN, ARKANSAS AND LOUISIANA

Municipality	1960 Population	Present Demand gpcd
Crossett, Arkansas	5,353	70
Warren, Arkansas	6,661	75
Arkadelphia, Arkansas	8,041	105
Malvern, Arkansas	9,518	85
Ruston, Louisiana*	13,940	110
West Monroe, Louisiana**	14,656	50
Bastrop, Louisiana	15,175	70
Camden, Arkansas	15,686	80
El Dorado, Arkansas	25,168	120
Monroe, Louisiana	51,931	120

* College supply serves 4,000±.

** Water system serves an estimated 20,000.

EXHIBIT B-1

WASTE ASSIMILATION REQUIREMENTS - PROJECTED 2010 WASTE LOADING

Water Supply Situation No. 1
(Assuming Benton Project Constructed in the Adjoining Saline River Basin)

1. Assumed Conditions

a. Waste Discharge

	mgd	Color	Population Equivalent
Municipal (90% of intake)	8	5	5,300
Industrial Pulp & Paper (90% of intake)	97	250	90,000
Total	105	-	95,300

b. Average Stream Conditions

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Temperature* (^{o}F)	71	58	49	49	51	58	65	73	83	86	87	80
f ($f_{20} = 1.0$)	0.97	1.15	1.36	1.36	1.35	1.15	1.01	0.95	0.80	0.75	0.70	0.83
DO (saturation)	9.0	10.0	11.3	11.3	11.3	10.0	9.5	8.5	7.7	7.7	7.4	8.1
DO (85% saturation)	7.7	8.5	9.6	9.6	9.6	8.5	8.1	7.2	6.5	6.5	6.5	6.9

*Based on Ouachita River at Felsenthal, Arkansas, six-year average 1950-1955.

EXHIBIT B-2

Water Supply Situation No. 1 (Continued)
(Assuming Benton Project Constructed in the Adjoining Saline River Basin)

2. Projected Flows - cfs

Month	Munc.	Ind.	Color* Assimilation	BOD Assimilation	At Camden: Total Required Flow	At Camden: Net Flow**	Additional Flow
Oct	15	170	610	320	795	105	690
Nov	15	170	610	230	795	660	135
Dec	15	170	610	50	795	3,580	---
Jan	15	170	610	50	795	2,010	---
Feb	15	170	610	50	795	1,390	---
Mar	15	170	610	230	795	2,300	---
Apr	15	170	610	250	795	2,180	---
May	15	170	610	355	795	7,060	---
Jun	15	170	610	680	865	470	395
Jul	15	170	610	680	865	475	390
Aug	15	170	610	680	865	525	340
Sep	15	170	610	440	795	410	385

Average Additional Flow - 195 cfs = 130 mgd

* To limit color in stream to 75 units assuming 30 units in stream flow at Camden, 250 units in industrial waste (pulp and paper) release, and 5 units in municipal discharge.

** Mean monthly flow at Camden during drouth year less mean monthly flow from Caddo River (not available if impounded).

EXHIBIT B-3

Water Supply Situation No. 2
(Assuming Only DeGray Project Constructed)

1. Assumed Conditions

a. Waste Discharge	mgd	Color	Population Equivalent
Municipal (90% of intake)	9	5	5,500
Industrial Pulp & Paper (90% of intake)	145	250	137,500
Total	154	-	143,000

b. Average Stream Conditions - Same as previous conditions (See paragraph 1b of Situation No. 1)

2. Projected Flows - cfs

Month	Munc.	Ind.	Color* Assim-ilation	BOD Assim-ilation	At Camden: Total Required Flow	At Camden: Net Flow**	Addi-tional Flow
Oct	15	250	735	590	1,000	105	895
Nov	15	250	735	420	1,000	660	340
Dec	15	250	735	270	1,000	3,580	---
Jan	15	250	735	270	1,000	2,010	---
Feb	15	250	735	270	1,000	1,390	---
Mar	15	250	735	420	1,000	2,300	---
Apr	15	250	735	540	1,000	2,180	---
May	15	250	735	700	1,000	7,060	---
Jun	15	250	735	1,280	1,545	470	1,075
Jul	15	250	735	1,280	1,545	475	1,070
Aug	15	250	735	1,280	1,545	525	1,020
Sep	15	250	735	1,000	1,265	410	855

Average Additional Flow - 435 cfs = 280 mgd

* To limit color in stream to 75 units assuming 30 units in stream flow at Camden, 250 units in industrial waste (pulp and paper) release, and 5 units in municipal discharge.

** Mean monthly flow at Camden during drouth year less mean monthly flow from Caddo River (not available if impounded).